

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

No. 876.

THE IMPROVEMENT OF A PORTION OF THE
JORDAN LEVEL OF THE ERIE CANAL.

By WILLIAM B. LANDRETH, M. Am. Soc. C. E.

PRESENTED FEBRUARY 7TH, 1900.

WITH DISCUSSION.

The Jordan Level of the Erie Canal extends from Lock 50, about 5 miles west of the City of Syracuse, N. Y., to Lock 51, near the Village of Jordan, N. Y., a distance of about 16 miles.

In the improvement of the Erie Canal, under the laws of 1885 and 1886, the work on the Jordan Level was embraced in Contracts Nos. 3, 4 and 5 of the Middle Division. The canal on that level runs for about 5 miles through a summit swamp, where the material is, first, 2 or 3 ft. of muck, then a mixture of marl and clay from 2 to 50 ft. in depth, then cemented gravel. Contract No. 4, extending from "a point 100 ft. west of the Camillas Road Bridge to a point 100 ft. west of the Peru Road Bridge, a distance of 6.31 miles," covers the worst part of the marl and clay formation. This contract was let to John Dunfee and Company, of Syracuse, N. Y., early in December, 1896, and work was begun thereon soon after by Belden and Seely of the same city, sub-contractors, and completed August 1st, 1898.

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H. C. Allen, Assoc. M. Am. Soc. C. E., and later, J. H. Grant, M. Am. Soc. C. E., were the engineers for the contractors, and Mr. M. B. Palmer, and, later, the writer, were in charge as Assistant Engineers for the State Engineer's Department.

The Superintendent of Public Works of the State was represented by several inspectors under the orders of J. Nelson Tubbs, M. Am. Soc. C. E., General Inspector of the Department of Public Works.

Believing that a description of the difficulties encountered in the marl beds, and of the methods used in overcoming them, may be of interest to the members of this Society, the following paper concerning the work on Contract No. 4 has been prepared.

The writer's knowledge of the work, prior to November 13th, 1897, is derived from the statements of the various contractors, engineers and inspectors connected with the contract; from the reports of the State Engineer and Surveyor; from testimony taken by the Canal Investigating Committee in the summer of 1898; and from an article* by Mr. George A. Morris, Resident Engineer of the Middle Division.

GENERAL TOPOGRAPHY.

Nine Mile Creek, the outlet of Otisco Lake, and one of the feeders of the canal, passes under the canal half a mile east of the eastern end of Contract No. 4. White Bottom Brook, the next stream of any size west of Nine Mile Creek, passes under the canal about half a mile east of the western end of the contract; and between those streams the canal runs through a nearly level plain from half a mile to 2 miles wide, bordered on the south by high hills and on the north by rolling country.

The original canal ran along the foot of the hills on the south side of the plain, crossing several small creeks between Nine Mile Creek and White Bottom Brook. These small streams meandered along the plain and emptied finally either into Nine Mile Creek or White Bottom Brook, depending on their position east or west of a low divide.

The present canal was located generally north of the former one and nearer the middle of the plain, necessarily crossing the small crooked creeks several times. As the water level of the present canal was originally below the level of the plain, the natural surface drainage was cut off and the canal prism formed a new channel for it.

*"Earth Slips on the Jordan Level Marl Beds of the Erie Canal," *Engineering News*, December 1st, 1898.

During the season of navigation the water in the canal held the water in the old creek channels above its natural level in places, and extensive swamps were formed on both sides of the canal. When the water was drawn down in the canal, during the closed seasons, the swamps were partly drained; and during a greater part of the year parties excavating marl and clay from the adjacent swamps, for the manufacture of Portland cement, pumped the water from their pits into the prism of the canal.

FIRST CONSTRUCTION OF THE PRESENT CANAL.

From all accounts, the first construction of the present canal was a difficult and costly job. Several attempts were made to drain the marl beds, so that the work on the prism proper could be carried on, and the work was completed finally by building a brush mat on the line of the proposed banks and dumping the material taken from the prism on it. Three separate contractors abandoned the work, and finally the State was obliged to finish it.

THE IMPROVEMENT OF 1895, 1896 AND 1897.

The plans of the State Engineer and Surveyor for the improvement of the Jordan Level, under the laws of 1895, provided for the lowering of the bed of the canal 1 ft. and raising the banks 1 ft. with the excavated material, thereby obtaining an additional depth of 2 ft. of water. The estimated quantities of material to be moved were those shown by cross-sections of the prism and banks taken during 1895, no allowance being made for the possible re-excavation of material which might slide into the prism.

The estimated cost of the work, by the proposal of John Dunfee and Company, figured on the published list of quantities for Contract No. 4, was \$154 471.

PROSECUTION OF THE WORK.

The water in the level was drawn down as low as possible through waste gates into several streams, but, owing to the accumulated mud in the prism, 2 ft. or more of water remained. To drain the prism thoroughly the contractor cut off all streams flowing into it, dammed off short sections where work was to be started and pumped the seepage water over the banks into the adjacent swamps. One small

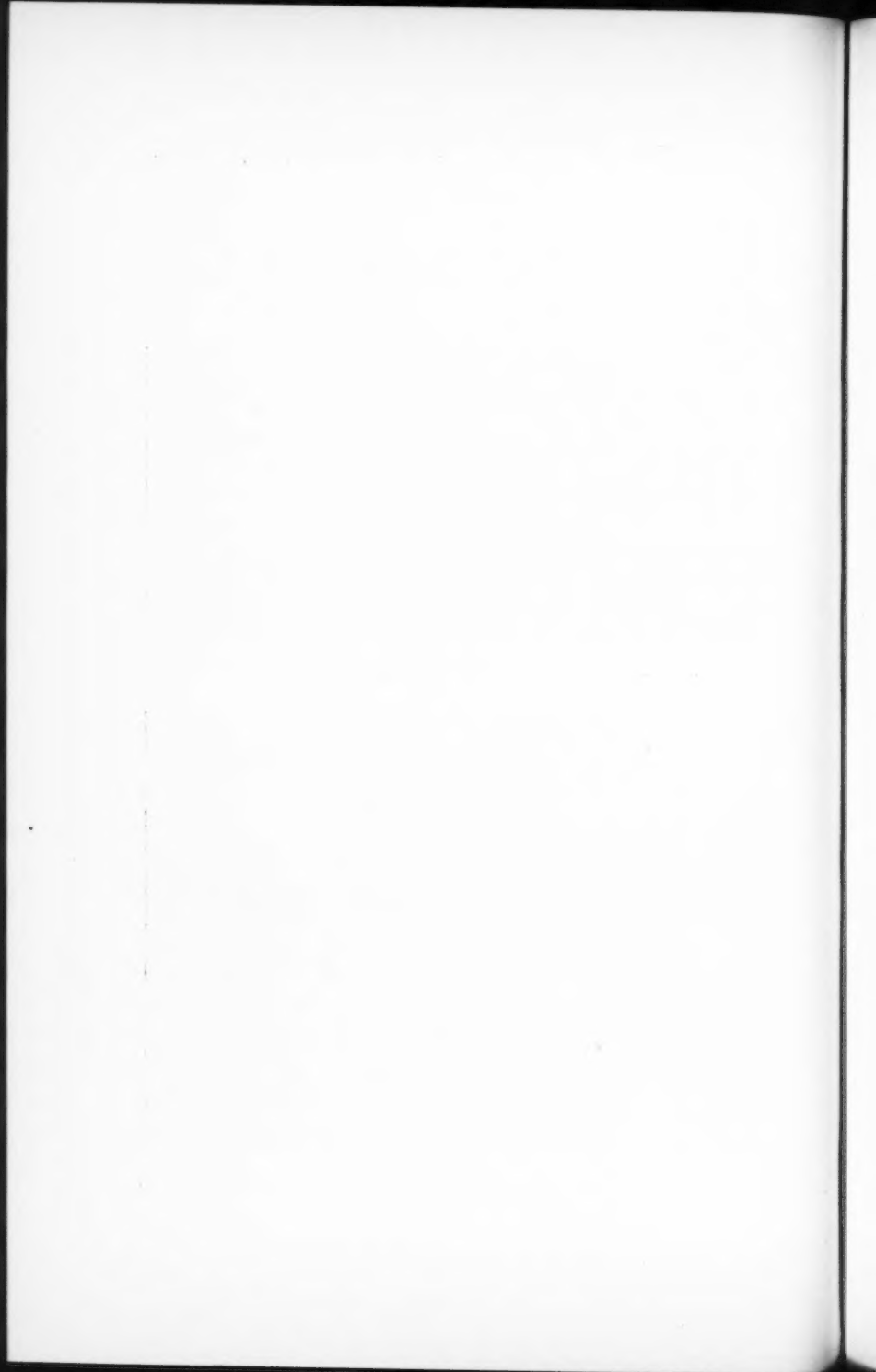
PLATE XLIX.
TRANS. AM. SOC. CIV. ENGRS.
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LANDRETH ON JORDAN LEVEL, ERIE CANAL.



FIG. 1.—EXCAVATION OF SOUTH DRAINAGE DITCH, SHOWING MARL FORMATION.



FIG. 2.—PORTION OF SOUTH DITCH, SHOWING BANKS CAVED IN WITHIN A MONTH AFTER THE COMPLETION OF THE DITCH.



stream was carried across the canal in a wooden flume and into an old State ditch leading to a branch of Nine Mile Creek. A great amount of water found its way into the prism of the canal, especially during the months of February, March and April, 1897, and several large centrifugal pumps were operated day and night in order to keep the prism even reasonably dry.

As soon as the excavation of the bottom of the prism was begun, in the soft material, the heavy banks settled, pushing up the mud in the bed of the canal; the banks and slope walls slid into the prism; bridge abutments began to settle, and there was great difficulty in making any progress at all. In several places, cross-sections made one day would show that the bed of the canal was higher than on the preceding day, though in the meantime several hundred men had been excavating mud from that portion. Piles, driven as far as possible into the underlying cemented gravel, would rise several feet in a night and have to be re-driven, though it was found that after being re-driven they did not rise again.

The general plan for holding the slope walls in place, during the early progress of the work, was that of driving short piles, or railroad ties, into the soft material at the foot of the walls, placing toe-beams against them and building a new wall from them to the bottom of the old one; but it was soon found that the pressure of the banks pushed the old and new work into the prism. Sheet piling was also tried, but with the same result. In some cases, where the material in the prism was undisturbed and only a ditch was dug along the foot of the slope wall to receive the row of piles and the toe-beam, the wall would stand, but when the remainder of the prism was excavated the wall and bank slid.

The surface of the cemented gravel was very uneven and its slopes changed abruptly, so that a structure would rest partly on the hard gravel and partly on the soft material, or on the piles driven into it, and would settle unevenly. The berme abutment of the Newport Bridge soon began to slide toward the canal, and, after several ineffectual attempts to hold it in place, it was torn down, a pile and timber foundation was put in and a new abutment built thereon. The piles under the abutment were 57 ft. long, driven as far as possible into the cemented gravel (probably 2 or 3 ft.), but when the backfilling of cinders behind the abutment had been carried about half way to the

top of it, the whole structure began to move toward the canal, followed by the bank and a neighboring hotel.

Timber struts were put across the bottom of the canal from the face of the new abutment to the foot of the slope wall opposite, and the movement of the abutment ceased.

The difficulties encountered during the winter of 1896-97, and the plans proposed for overcoming them, are described in a report* made to the State Engineer by Mr. W. H. H. Gere, Division Engineer on the Middle Division of the canal, as follows:

"In preparing the preliminary estimate for Contracts Nos. 3, 4 and 5, consisting of the Jordan Level, the conditions and difficulties to be encountered to lower the prism 1 ft. were not understood and could not have been anticipated. For about 5 miles the canal is cut through a swamp, the surface of the adjoining land is several feet above the surface of the water in the canal, and upon either bank the material originally excavated was deposited, forming heavy banks. The surface soil is muck, underneath which is quicksand and marl reaching in some places 40 ft. in depth below canal bottom. The surface of the swamp being high enough, was drained into the canal, as no other remedy has been provided; in order to do the work in the prism all these streams had to be closed, thus allowing the swamps to fill with water. As a result the whole mass of marl and quicksand became soapy to such an extent that the material in the bottom of the prism would raise faster than it could be raised with modern dredges. The heavy spoil banks settled, raising the prism and carrying down the towing-path and old slope wall and the bench on which it rested on the berme side. About one-half of the length of the contract has been excavated and the slope-walls built. Just before the opening of the canal, the towing-path settled several feet, and the only remedy available was adopted by bridging with material on hand and planking the surface for a towing-path. The most difficult portion of the work is yet to be done. How to change the conditions to enable the contractors to do the work was a question of serious moment. After a thorough conference with the State Engineer and Superintendent's Department, it was finally agreed that—

"*First.*—The swamps must be drained.

"*Second.*—That in order to form a foundation for slope-wall and to prevent the material raising in the prism at each side from the weight of the heavy spoil banks upon both sides of the canal, it was decided to drive a close row of piles at the toe of the slope-wall through the soapy material into the underlying strata of hard material ranging from 15 to 40 ft., upon which, as a foundation, the slope-wall will be built.

* Annual Report of the State Engineer for 1897, pp. 222, 223, 224.

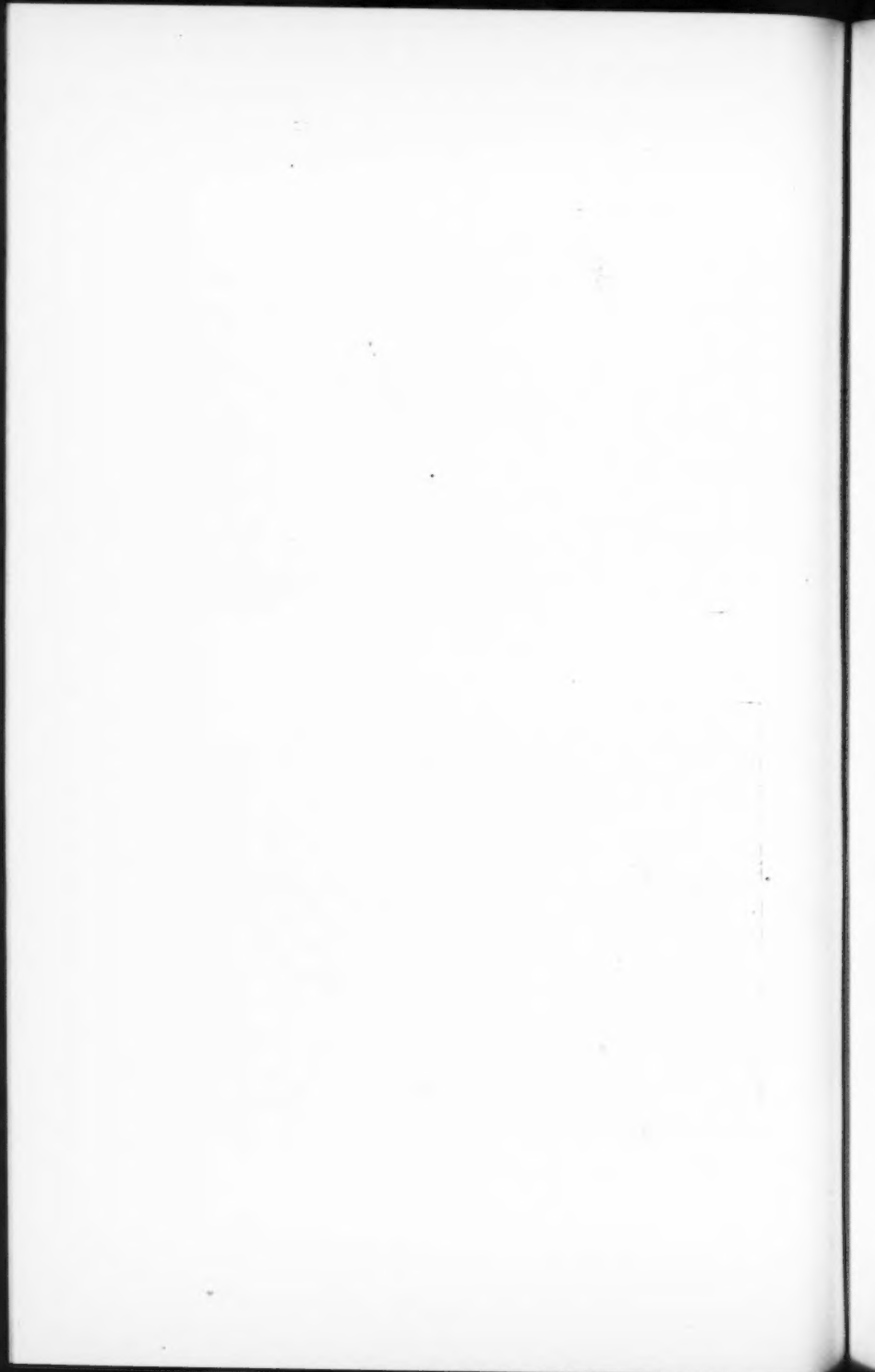
PLATE L.
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FIG. 1.—EXCAVATION FOR STRUTS IN MARL BEDS.



FIG. 2.—PLACING STRUTS IN GROUPS OF FIVE.



"In order to drain the swamp, it was decided to construct a culvert under the Nine Mile Creek feeder on Contract No. 3, to give an outlet into Nine Mile Creek, and excavate ditches upon both sides of the canal through the swamp, covered with timber, of sufficient capacity to drain the swamp without allowing it to enter the canal. This work and the piling not contemplated at the time of making the estimate will cost about \$80 000.

"The material in the prism in much of the distance completed was quadrupled from raising. Slope and vertical walls and bridge abutments after completion would slide into the canal and have to be relaid, sometimes more than once. The troubles encountered upon this contract are so serious and various, that an attempt at description will give but an incomplete idea of their magnitude, and an approximate estimate of the final cost of the work cannot now be made; but if the result from ditches and pile protection proves all that is anticipated, the work to complete the contract will be comparatively easy and will be done without doubt the coming winter.

"I have prepared the foregoing statement, not as a justification of the cost of the work under this contract, in excess of the estimate made prior to letting the work, but as a matter of history of the most difficult work in all its surroundings upon the canals of this State, and I know that this effort falls far short of doing full justice."

Early in the progress of the work in the marl beds it was found to be impossible to measure or calculate the quantity of material removed from the prism where the bottom was steadily rising, and payment was made to the contractors by the method known on State work as by "force account," whereby they were paid for the wages of the men, and for teams, etc., with 10% added for profit, wear and tear of tools and depreciation of plant.

The culvert under Nine Mile Creek feeder and the drainage ditches were built during the fall of 1897, and no further trouble was encountered from the surface water. As the side ditches were at a higher level than the bottom of the prism, pumping was necessary to free it from ground-water, but to a less extent than formerly.

During the fall of 1897 piles were driven in a close row at the foot of the side slopes of the prism, from boats, over the greater part of the marl beds. Test piles were driven every 100 ft., or closer where necessary, to determine the length of, and line for, the close row, and very good alignment was secured in most cases.

At the close of navigation, in December, 1897, the general condition of the work on the contract was as follows: A part of the prism excava-

tion in the marl beds had been completed; drainage ditches had been dug; long piles had been driven at the foot of the slide slopes over the greater part of the marl formation; a new berme abutment had been built for the Newport Bridge, and the berme abutment for the Memphis Bridge had been underpinned with heavy stone; the greater part of the tow path had been graded; a large amount of old slope wall had been underpinned and topped out up to the new grade, and a new wire fence had been built over several miles of the right-of-way.

A great amount of opposition was met from farmers owning land through which the new drainage ditches passed, as the State had not bought the right-of-way, and a dozen or more suits had been brought against the sub-contractors for trespass. A test case has since been carried to the Appellate Division of the Supreme Court, and, thus far, the decision has been against the sub-contractors.

SEASON OF 1897 AND 1898.

During the summer of 1897 the contractors had delivered large quantities of slope-wall stone and gravel lining by boat, and deposited it along both banks of the canal, for future use. When the prism was drained, at the close of navigation, early in December, 1897, the banks began to slide, especially in that part of the marl beds where they had been loaded with stone and gravel, and a corresponding rise of the material in the bottom of the prism followed.

On some sections of the work the long piles driven during the summer remained in place, but where the soft formation was deepest, from Station 360 to Station 410, and at Newport Bridge, they moved several feet toward the middle of the canal after the water was drawn down. The marl and clay in the canal banks would break off with a nearly vertical fracture, settle from 4 to 8 ft., and a mound of mud would rise in the bottom of the canal. For a length of about 2 miles, east of Newport Bridge, the long piles remained in place, and little sliding of the banks occurred. It soon became apparent that the plan of driving long piles at the foot of the walls would not suffice in all cases, and a conference of the officials and engineers of both departments was held, to devise some effective means of construction.

As the result of that conference the following plan was adopted. To drive a close row of piles along the toe of the slope walls, passing

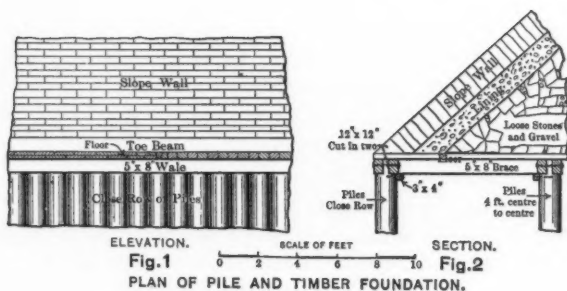


Fig. 1 ELEVATION. Fig. 2 SECTION.
PLAN OF PILE AND TIMBER FOUNDATION.

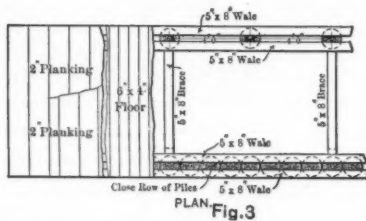


Fig. 3

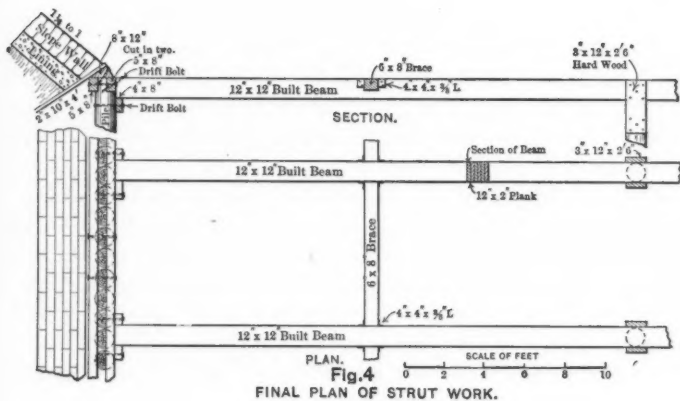


Fig. 4
FINAL PLAN OF STRUT WORK.

through the soft material and as far as possible into the underlying hard material; drive a second row of piles in the bank 8 ft. back of the first row, spacing them 4 ft. between centers, excavate between the two rows down to the new bottom of the prism; tenon each row of piles and bolt a 5 x 8 in. waling piece along each side of each row; brace the two rows of piles apart opposite every other pile in the back row, by a 5 x 8-in. timber; lay a floor of two courses of 2 x 12-in. plank on the structure thus formed; bolt a heavy toe-beam along the front edge of the floor to hold the toe of the new slope wall; start the new slope wall and fill behind it with stones and gravel.

In building by this plan, owing to the time necessary to excavate between the piles down to the new canal level, tenon the piles, and put the waling timbers and cross-struts in place, it was found that the back row was forced toward the canal, so as to narrow the width of the foundation; and in some cases the entire foundation moved several feet toward the prism while the slope wall was being built.

It is possible that the plan could have been carried out successfully if more rapid methods of excavating could have been used; but the unstable bank would not support the weight of power excavators, and the nearness of the date for opening the canals for navigation prevented the adoption of any plan for the removal of the banks, which would take time for installation.

After a few hundred feet of foundation had been put in place with only partial success, a conference of the officials of the two departments was held, and the following plan was adopted:

A row of piles was driven on the line of the toe of each slope wall; waling timbers were spiked on each side of each row, and struts of 12 x 12-in. built-beams were placed across the prism at 8-ft. intervals, butting against the front waling timber at each row of piles; a toe-beam was bolted on the top of each row of piles; and a floor for the slope wall was built thereon by driving 2 x 10-in. planks, 4 ft. long, into the material of the old bank. To prevent any vertical movement of a strut, a pile was driven to hard bottom at its middle; cut off 6 ins. below the level of the ends of the strut, and fastened securely to it. Lateral movement of the struts was prevented by placing between adjacent ones braces made of 6 x 8-in. timbers.

The abandoned plan is shown in Figs. 1, 2 and 3, and the final plan in Fig. 4.

PLATE LI.
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FIG. 1.—SLIDE IN TOW PATH NEAR NEWPORT BRIDGE.



FIG. 2.—SLIDE IN MARL.



The best method of procedure in putting the construction in place, and that followed generally, was to drive the middle row of piles first; excavate trenches across the prism for the struts; put them in place with their middle resting on the driven pile and their ends on temporary mud-sills to prevent their sinking into the mud; drive the side rows of piles; bolt the wales in place; cut the ends of the struts off in line and drift-bolt them to the wales, wedging between the end of the strut and the wale with hard wood when necessary; build the floor and slope wall; and excavate the remainder of the prism as soon as convenient.

To lessen the sliding of the banks during the placing of the struts, five of them were put in place, then a space was left for five more, and a group of five was placed the proper distance ahead; the gaps being filled by a second gang of men.

About 3 700 lin. ft. of canal between Station 360 and Station 410 and 500 lin. ft. near the Newport Bridge were repaired successfully by the final plan. Wherever the piles driven during the former summer had remained near the line of the new work they were used, but in most cases they had moved so far out of line that new ones had to be driven. The long piles were chiefly Michigan pine, from 30 to 50 ft. long, "not less than 9 ins. in diameter at the small end, under the bark, nor less than 12 ins. 3 ft. from the butt." Some piles which had been driven from 2 to 3 ft. into the cemented gravel, when forced out of line by the side pressure, broke off at the surface of the gravel with a sharp, snapping sound. Where the side banks were very soft the piles were driven in a close row, to serve also as sheet piling, to prevent the material in the banks from working under the toe of the new slope walls. In other cases they were spaced 3 or 4 ft. between centers. Loose stones and gravel were used in filling back of the slope walls, the quantity used being determined by a tally kept of the number of loads delivered in wagons of a known capacity.

As before stated, the berme abutment of the Newport Bridge had been rebuilt and braced against the opposite vertical wall during the summer of 1897, and up to the closing of navigation but little sliding of the tow-path abutment had occurred, though the vertical wall in front of it had settled several feet. The tow-path abutment rested on mud-sills at about the new water level of the canal and 10 ft. above that of the bottom of the new vertical wall to be built in front of it.

To keep the abutments in place during the construction of the new vertical wall, and the consequent removal of the temporary struts, a new brace was built between them. The new brace was similar to an oil-well derrick laid on its side, its base covering a space of about 12 ft. x 12 ft. of the berme abutment, and its top pressing against the face of the tow-path abutment high enough to permit of the construction of the new vertical wall. The placing of a new brace, building a pile and timber foundation for the vertical wall, and the construction of the wall itself were completed without any movement of either abutment taking place. Inclined struts were built from the back of the foundation of the new wall to the bottom of the front face of the tow-path abutment to prevent its sliding whenever the main brace was removed. Several small slides occurred in the banks when the water was let into the level, in May, 1898, where no struts had been used, but in all cases, except one, they were repaired before the level was full.

DESCRIPTION OF THE MATERIALS EXCAVATED.

The marl varies in color from a pure white to a yellowish white. It is handled readily when dry or plastic, but becomes very slippery when wet. It lies in horizontal layers, varying from a few inches to a foot in depth, with a very thin layer of black decayed vegetable matter separating them. The marl deposit, taken as a whole, varies from 2 to 15 ft. in depth, and its depth often changes abruptly.

The clay underlies the marl, and is dark gray in color, with some layers which are nearly the color of common blue clay. It lies in horizontal layers, varying from 1 in. to 2 ft. in depth, separated by a very thin layer of a lighter colored and finer clay, upon which the different layers slide when disturbed. The clay can be handled readily when plastic or dry, but flows like water when saturated. When dried carefully, so as to prevent caking, all of it passes a 60-mesh screen and about 10% is held by a 100-mesh screen. It shrinks about 10% when dried, and contains from 0.08 to 0.10 of 1% of sharp sand. In some parts of the clay beds there is a layer of sharp sand from 1 to 2 ins. thick between the clay and the underlying cemented gravel.

At the works of the Empire Portland Cement Company, at Warners, N. Y., Portland cement of excellent quality is made by mixing equal parts of marl and clay. The process of manufacture is known as the "semi-humid," the output of the works being 600 bbls. per day.

PLATE LII.
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FIG. 1.—SHOWING EXTENT OF SLIDE NEAR NEWPORT BRIDGE, AND CHARACTER OF MASONRY IN NEW VERTICAL WALL.



FIG. 2.—STRUTS ACROSS PRISM NEAR NEWPORT BRIDGE, AND VERTICAL WALL READY FOR CONCRETE COPING.



The following analyses of the clay and marl are taken from a description of the works of the Empire Portland Cement Company.*

	Percentage of marl.	Percentage of clay.
SiO ₂	0.26	40.48
Al ₂ O ₃ and Fe ₂ O ₃	0.10	20.95
CaOCO ₂	94.39	25.80
MgOCO ₂	0.38	0.99
Loss by ignition.....	4.64	8.50

When saturated, the clay acted like quicksand, and some persons called it by that name; but, to the writer's knowledge, no true quicksand (*i. e.*, a mixture of rounded particles of sand and clay, the sand predominating) was encountered on the work.

In a few places a fine, clean sand was encountered, which was forced up in miniature geysers by the under pressure of the water, and at first sight might be taken for quicksand; but true quicksand, which will flow through crevices and holes where pure sand will not, and which, in the writer's experience, has always been mixed with a finely divided clay, was not found on Contract No. 4.

The cemented gravel consisted of gravel from the size of a pea to pieces 3 ins. in diameter, cemented with a material which, in color and apparent composition, resembled the marl closely. When blasted and dumped in a pile, the cemented gravel re-cemented itself to such an extent that, at the end of a few weeks, blasting had to be resorted to in order to loosen it up.

The writer was informed by the chemist of the Empire Portland Cement Company that the cemented gravel was mostly carbonate of lime, similar to the marl.

The rock was chiefly shale, in ledges from 3 to 10 ins. thick, and was drilled and blasted, except where the cutting was only a few inches thick. Rock, which was very hard when excavated, slaked and turned into mud after a few weeks' exposure to the weather. The cemented gravel also softened up for a few inches in depth when in contact with water for several weeks, making it a very treacherous material for side slopes, unless protected by a slope wall of stone. All the soft material removed from the prism, during the winter of 1897-98, was carried at least 100 ft. back from the canal and spread over the surface of the adjacent swamps to lessen the weight on the banks.

* *The Engineering Record*, July 16th, 1898.

TABLE No. 1.—ESTIMATED QUANTITIES AND PRICES BID ON CONTRACT
No. 4.

Quantities.	Items.	Unit.	Prices.
1....	Grubbing and clearing.....	Lump sum.	\$500.00
1....	Bailing and draining.....	"	\$ 000.00
150 000....	Excavation of earth.....	Cubic yards.	0.275
4 500....	" rock.....	"	1.00
500....	" masonry.....	"	0.70
5 000....	Rock channelling.....	Square feet.	0.10
1 000....	Embankment.....	Cubic yards.	0.30
17 000....	Lining.....	"	1.00
1 000....	Puddling.....	"	0.30
500....	Files delivered.....	Lineal feet.	0.10
500....	" driven.....	"	0.15
50 000....	" at foot of walls, delivered.....	"	0.09
45 000....	" driven.....	"	0.09
1 000....	White oak timber and plank.....	1 000 feet, B. M.	50.00
4 000....	Pine.....	"	30.00
246 000....	Hemlock.....	"	16.00
755 000....	Spruce.....	"	17.00
850....	Bridge, culvert and receiver masonry.....	Cubic yards.	7.00
40....	" coping.....	"	16.00
50....	Vertical wall, Portland cement.....	"	6.00
1 100....	" laid dry.....	"	3.50
16 000....	Slope and pavement wall.....	"	2.47
2 200....	Portland-cement concrete.....	"	5.00
5....	Asphaltic concrete.....	"	15.00
10....	Loose stone filling.....	"	2.00
10....	Portland-cement pointing.....	Square yards.	0.50
44....	Pavement wall.....	Cubic yards.	5.00
500....	Cedar posts, set.....	Lineal feet.	0.40
1 000....	Wrought iron and steel.....	Pounds.	0.05
10 000....	Cast-iron pipe.....	"	0.02
3 500....	Spikes and nails.....	"	0.05
3....	Raising bridges.....	Each.	800.00
3....	Painting.....	"	100.00
DEDUCT MATERIALS FURNISHED BY STATE.			
20....	Dressed coping.....	Cubic yards.	5.00
170....	Face stone.....	"	3.50
180....	Backing and vertical wall stone.....	"	1.50
1 700....	Slope wall stone.....	"	0.80
10....	Loose stone.....	"	0.50
2 000....	Hemlock.....	1 000 feet, B. M.	10.00

The clay was very heavy, weighing from 80 to 83 lbs. per cubic foot; and from $1\frac{1}{2}$ to 2 cu. ft. to a wheelbarrow load was all that a man could push up the plank runways out of the prism. Most of the clay and marl was removed in wheelbarrows, although a clam-shell derrick was used with success on part of the work east of Warner's Bridge, where the material was comparatively dry.

In the marl beds, the slope walls were built of quarry stone, it being found that the cobbles of which the old wall was composed slid on each other, when covered with the marl or clay, to such an extent that they could not be kept in the wall.

TABLE NO. 2.—LIST OF QUANTITIES AND UNIT PRICES GIVEN IN THE MONTHLY ESTIMATE FOR AUGUST, 1898, ON CONTRACT NO. 4.

Quantities.	Items.	Unit or Lump-sum price.
1.....	Grubbing and clearing.....	\$500.00
1.....	Bailing and draining.....	3 000.00
308 164 cu. yds.	Earth excavation.....	0.275
25 062 " "	Rock ".....	1.00
526 " "	Masonry ".....	0.70
31 060 " "	Earth embankment.....	0.80
58 915 " "	Lining.....	1.00
276 030 lin. ft.	Piles delivered.....	0.10
362 650 " "	" driven.....	0.15
84 088 " "	" at foot of walls delivered.....	0.09
44 088 " "	" " " " driven.....	0.09
250 ft., B. M.	White oak, timber and plank.....	50.00
19 650 " "	Pine, " " ".....	30.00
1 055 600 " "	Hemlock, " " ".....	16.00
230 860 " "	Spruce, " " ".....	17.00
705.5 cu. yds.	Bridge abutment masonry.....	7.00
29.4 " "	" coping.....	16.00
2 859.9 " "	Vertical wall, Portland-cement.....	6.00
295 " "	" " laid dry.....	3.50
44 800 " "	Slope and pavement wall.....	2.47
339.5 " "	Loose stone filling.....	2.00
4 300 " "	Portland-cement concrete.....	5.00
240 sq. yds.	" " pointing.....	0.50
44 cu. yds.	Pavement wall.....	5.00
680 lin. ft.	Cedar posts, set.....	0.40
45 240 lbs.	Wrought iron and steel.....	0.05
176 440 " "	Cast-iron pipe.....	0.02
38 030 " "	Spikes and nails.....	0.05
3 " "	Raising bridges.....	300.00
3 " "	Painting ".....	100.00
MATERIALS DELIVERED.		
2 000 ft., B. M.	Hemlock timber and plank.....	12.00
400 lbs.....	Spikes and nails.....	0.02
DEDUCT MATERIALS FURNISHED BY STATE.		
84.4 cu. yds.	Face stone.....	3.50
162.4 " "	Backing and vertical-wall stone.....	1.50
9 737.4 " "	Slope-wall stone.....	0.80
64 100 ft., B. M.	Hemlock.....	10.00
EXTRA WORK AT A PRICE AGREED UPON.		
106 lin. ft.	Cement pipe, 22 x 28 ins.....	1.35
255 " "	" " 18 ins. diameter.....	0.50
98 412 " "	Piles, 30 ft.—35 ft. long, delivered.....	0.16
61 522 " "	" 40 ft.—45 ft. ".....	0.21
4 047 " "	" 50 ft. ".....	0.28
EXTRA WORK, AS PER RESOLUTION OF CANAL BOARD PASSED SEPTEMBER 30TH, 1897.		
1.....	Grubbing and clearing State ditches.....	1 000.00
1.....	Bailing and draining ".....	500.00
EXTRA WORK, PAID FOR WITH PROFIT ALLOWANCE.		
Total as Per Estimate of November 1st, 1897.....		33 337.17
EXTRA WORK, AS PER RESOLUTION OF CANAL BOARD, PASSED FEBRUARY 2d, 1898.		
1.....	Bailing and draining White Bottom Brook culvert...	1 325.00
1 855 lbs.....	Lead, White Bottom Brook Culvert.....	0.10
EXTRA WORK, AS PER RESOLUTION OF CANAL BOARD, PASSED MARCH 31st, 1898.		
1.....	Raising Newport Bridge.....	600.00
470 bbls.....	Portland cement used in concrete in excess of contract proportions.....	2.00
EXTRA WORK, PER RESOLUTION OF CANAL BOARD, PASSED FEBRUARY 2d, 1898.		
General "force account" work.....		80 982.14

COST.

The cost of the work in the marl beds, being scattered through many monthly estimates, can only be determined by a laborious examination of the field and estimate books; but the writer believes the following statement thereof to be a close approximation to the actual cost to the State.

Side ditches (on Contract No. 4)	\$45 000
Piling to hold banks.....	100 000
Strut work.....	116 000
Total	<u>\$261 000</u>

As stated previously, the estimated cost of the work on Contract No. 4, at the letting of the contract, was \$154 471, calculated on the quantities shown in Table No. 1, and at the prices bid.

Table No. 2 is a copy of the last monthly estimate made by the writer on Contract No. 4, and includes all the work done thereon; but he is informed that a final settlement has not yet been made.

The quantities and prices only are given, except in cases where a lump sum was paid, and on the "force account" work. The official copy of the estimate contains the totals in dollars for each item, but a full copy is not at hand.

The total cost of the work as shown by the foregoing estimate was \$606 854.52, and the writer is informed that an estimate by the office force of the Middle Division, from the field notes on Contract No. 4, makes the true amount about \$400 less.

A seeming excess of length of piles driven, over the length delivered, as stated in the estimate, is explained by the fact that all piles except those at the foot of the walls were driven at \$0.15 per foot; making a real excess of 47 351 ft., in piles delivered. Of this excess of piles delivered, 13 055 ft. was the length of cut-off and the remainder the length of piles on hand at the completion of the work, the property of the State.

GENERAL FORCE ACCOUNT WORK.

The management of the work on "force account" was placed in the hands of a competent General Superintendent of the Department of Public Works who changed the force of workmen as necessary, fixed the rate of wages, and had full control of the laborers.

The time was kept by one timekeeper for the Contractor, one for the Department of Public Works, and one for the Engineering Department; and every day's account was compared and checked that day, material differences in the accounts of the three timekeepers being referred to the Contractor, General Superintendent and Engineer for investigation and settlement.

The General Superintendent and the Engineer worked in harmony and had daily conferences regarding the best methods of prosecuting the work. Payments were made only on the sworn statements of the Engineer and his timekeeper as to the accuracy of the pay rolls; and every precaution was taken against errors creeping in.

The number of men working on "force account" varied from 200 to 600, depending on the amount of work going on.

DISCUSSION.

Mr. Hazen. ALLEN HAZEN, Assoc. M. Am. Soc. C. E.—There are, perhaps, few materials about which more different opinions are held than quicksand. A good definition of this substance is greatly to be desired. This paper contains a definition of quicksand which differs considerably from the idea which the speaker has entertained, and he will present briefly the idea which he has held, with the hope of starting a discussion leading to something more definite upon this subject.

Mr. Landreth's definition of quicksand is: "A mixture of rounded particles of sand and clay, the sand predominating."

The speaker's idea of quicksand is: an even-grained sand, containing for the time more water than would normally be contained in its voids, and, therefore, with its grains held a little distance apart, so that they flow upon each other readily. The sand may be either coarse or fine, generally it is extremely fine. It is the speaker's idea that quicksand in general contains no clay. It may be that some materials contain a little clay, and still act as quicksand; but, if so, that they act as quicksand notwithstanding the clay, and not because of it. A material containing clay particles in considerable quantity is cohesive and impervious. Water may press it out of shape, make cracks in it and rush through it. Under some conditions the whole mass, under heavy pressure, may flow slowly like molasses, but with water it will never make an intimate mixture capable of flowing through small openings and behaving much like water, which is the characteristic property of quicksand.

The sand in a mechanical filter is a good illustration of quicksand. The sand is placed in a tub, with screens or other drainage apparatus at the bottom. The water flows downward through the sand during filtration. Occasionally, the flow is reversed to wash the sand. When the current is downward the sand is firm, and it remains firm after it is drained. If one steps upon it the track hardly shows. When the sand is washed by an upward current, it is lifted by the water, and occupies, perhaps, 10% more volume than it did with the downward current, and in this condition it is suspended in the water, and is so soft that a stick can be pushed into it with but little more resistance than would be offered by so much water.

As the voids in the sand are increased, the friction is greatly reduced, until a point is reached where the friction just balances the excess of weight of the sand over water, and this condition may be maintained indefinitely, the upward current of water just sufficing to hold the sand in a state of suspension.

In this condition it is ideal quicksand. The phenomenon is precisely the same whether the sand is of wind-worn spherical grains or of the

most angular grains of crushed quartz. In either case the sand is Mr. Hazen. made quick by the passage upward through it of a current of water so rapid that the friction which it encounters more than equals the weight of the sand, and as a result the sand is lifted. If the upward rate were somewhat less, the weight of the sand would exceed the friction, and the sand would not become quick, but would remain solid and firm, as with the downward current.

The upward velocity required to lift a sand in this way is a direct function of the size of the sand grains, and can be computed. The sand used in mechanical filters has an effective size of from 0.40 to 0.60 mm., and the velocity used in washing is such that the friction is more than equal to the excess in weight of the sand over water, but is not three times as great. If it were, some of the sand would be carried away.

Table No. 3 shows the computed velocities at which the friction equals the excess in weight of sands of various grain sizes, or, in other words, the velocities at which the sands will just be lifted.

TABLE No. 3.—COMPUTED VELOCITIES REQUIRED TO LIFT SANDS OF VARIOUS GRAIN SIZES.

At a temperature of 50° Fahr.

Effective size of sand.	Velocity of solid column of water, in meters per 24 hours.	Velocity of solid column of water, in inches per hour.
0.50 mm.	250	410
0.40 "	160	262
0.30 "	90	148
0.20 "	40	65
0.10 "	10	16
0.05 "	2.5	4
0.03 "	0.9	1.5

This table, perhaps, gives an indication of the reason why quick-sands are usually fine sands. The finest mortar sand has an effective size of from 0.20 to 0.30 mm. To lift it, requires an upward velocity of from 5 to 12 ft. per hour, a velocity greater than those which generally occur in the ground water about excavations. That is to say, sand of this coarseness will only act as quicksand where the ground-water currents are unusually strong. With sand 0.10 mm. in diameter, a velocity of only 16 ins. per hour is required to lift it—a velocity which is probably quite common—while the lower velocities of 4 and 1.5 ins. per hour, required to lift sands with effective sizes of 0.05 and 0.03 mm., respectively, are almost sure to exist where excavations are made below the ground-water level in pervious materials; and where sands of these sizes exist they are almost sure to act as quicksands.

Mr. Hazen. There is a condition which may make a sand quick which at first sight would seem to be different from that mentioned, but which in reality is but a variation of it. It is when sand in apparent equilibrium is made quick by a sudden shock or blow. Let us suppose a layer of sand with an effective size of 0.05 mm. and 3 ft. deep, in which the voids are 42%, entirely filled with water. The grains are in a not very stable equilibrium, and this sand is capable of being compacted to 40% of voids. A smart blow or sudden pressure will disturb the equilibrium, and the sand will be suspended by the water which it contains. It will shrink 5% in going from 42 to 40% of voids; and, under the conditions assumed, if perfectly drained at the bottom, half an hour will be required for the excess of water to drain out of it. During this time it will be quicksand. This phenomenon may be seen on many lake shores where the sand is held full of water by capillarity, but in this case the sand is usually coarser, and the length of time that it remains quick is but a small fraction of the above, perhaps only a minute or two, or even less.

A number of samples of material, presumably quicksand, obtained by borings in connection with some of the deep waterways investigations, and which were labeled as mixtures of clay and sand, have been handed to the speaker by Mr. E. P. North. Under the microscope these materials proved to be entirely free from clay, and consist of particles from 0.03 to 0.10 mm. in diameter, having effective sizes of approximately 0.04 mm. Ninety per cent. or more will pass a sieve with 200 meshes per lineal inch. These materials contain a little lime, but, so far as this is the case, the speaker is inclined to think that the lime tends rather to keep them from acting as quicksand than otherwise.

The question may be raised as to the propriety of extending the name of sand to these extremely fine materials. Materials of these sizes occur quite freely in Nature, in which the particles are mostly silica, occasionally with a mixture of hard silicates. Under the microscope they appear precisely like sand. The particles are angular, the arrangement of the particles and the percentage of voids are substantially the same as with coarse sands. The relation of these materials to ordinary sand is much the same as that of sand to gravel, but it is not correct to speak of sand as fine gravel, and it may not be correct to speak of these materials as fine sand. The terms silica dust and sand dust have been suggested, but they imply dryness, and do not seem suited to quicksand. The word silt is also used, but this suggests a somewhat different meaning. Microscopic sand would perhaps be a better term.

Clay is an entirely different substance. Mr. H. W. Wiley,* Chemist of the United States Department of Agriculture, makes the following statement in regard to the properties of clay:

* "The Principles and Practice of Agricultural Analysis," p. 232.

"The percentage of pure clay is about 75% in natural clays, 45% in heavy clay soils, and 15% in ordinary loamy soils. When freshly precipitated by brine it is gelatinous, resembling a mixed precipitate of iron and aluminum oxides. Its volume greatly contracts on drying, clinging tenaciously to the filter, from which it may be freed by moistening. On drying it becomes hard, infriable and often resonant. It usually possesses a dark brown tint, due to iron oxide. Under the action of water it swells up like glue, the more slowly as the percentage of iron is greater. In the dry state it adheres to the tongue with great tenacity. According to Whitney the finest particles of colloidal clay have a diameter of 0.0001 mm. With a magnifying power of 350 diameters, however, Hillgard states that no particles can be discerned."

The clay particles are tens, if not hundreds, of times smaller than the smallest sand grains here considered, and differ from them, both physically and chemically.

It is the speaker's impression that there is a good deal of looseness in distinguishing between clay and microscopic sand. Sand is often so fine as not to be gritty, and when moist it has many of the properties of clay. It differs from clay in its lack of adhesion when dry. A very small percentage of clay, however, makes it adhesive.

The speaker thinks that in many instances microscopic sand, either entirely or nearly free from clay, has been mistaken for clay. So far as he knows, nearly all clay contains more or less microscopic sand, and the percentage of sand may become quite large before it ceases to be called clay. The microscope at once reveals the difference between clay and sand, and there is no good reason for confounding them.

GEORGE W. RAFTER, M. Am. Soc. C. E. (by letter).—In discussing Mr. Rafter. this paper the writer recognizes that Mr. Landreth was not in any degree responsible for the plans adopted, but that he is historian merely of what, for lack of thorough knowledge of the conditions, turned out to be an exceedingly unsatisfactory piece of construction.

As to why this particular construction was so unsatisfactory, the writer will not now attempt to determine. The discussion of that question pertains rather to a broad history of the Erie Canal, in which the results of many years of management of a great public work on political lines are traced to final philosophical conclusions. This part of the subject is of extreme interest and could be expanded indefinitely. Nevertheless, the writer leaves it untouched any further than to remark that the absence of systematic boring records along the Erie Canal probably led to some serious errors of omission.

The methods finally adopted are detailed clearly in the paper. Taken in conjunction with the long struggle against the inevitable, which preceded their adoption, they have seemed to the writer to indicate that, from first to last, this work was conducted on experimental lines purely. Apparently, no one quite grasped the real scope

Mr. Rafter. of the problem presented. In order to indicate the basis for this position, let us outline the physical conditions to be met.

As indicated in the paper, the marl varies in depth from 2 to 15 ft. Beneath this is found soft clay to a depth of 40 to 50 ft. from the surface of the ground. The surface soil is swamp muck.

Such conditions indicate clearly that the margins of excavations should be kept clear of extraneous loads. Nevertheless, as shown by the photographs, this precaution was ignored. Even after a year's experience the contractors were allowed to weigh down the margins of drainage ditches with freshly excavated material. The sliding of the banks of these ditches is therefore merely an illustration that like causes produce like results.

It is clear to the writer, therefore, that the first thing to be done was to clear the margins of excavated material. The next step was to remove the muck above the marl for some distance back on either side of the main channel. After this was done the deepening of the channel, even for several feet, would have been a very simple matter. The slopes would properly have been made flat, in this system of construction.

If embankments over such material are necessary, the proper procedure is to strip the marl for 50 to 100 ft. on each side of the channel, and construct the embankment with a berm 10 to 20 ft. wide on the inside. In this way the writer believes that a canal can generally be constructed through marl without special extra expense, other than for wide right of way. In the present case, if it is deemed necessary to maintain towing paths on the original lines, a timber platform on piles will answer every purpose.

From near the foot of Cayuga Lake to some distance below Mosquito Point, Seneca River flows over marl beds, and from the New York Central and Hudson River Railway Viaduct to Mosquito Point, a new channel was cut in this material about 25 years ago. This channel extends from 6 to 8 ft. into marl, and its banks stand at a slope of about $1\frac{1}{2}$ to 1. In 1858, or thereabout, a new channel for Canandaigua Outlet was also cut through Seneca River marl in the vicinity of Montezuma Aqueduct, which has not given any trouble by the rising of the bottom, such as perplexed the Erie Canal engineers at Warners, in 1896-97. The writer cannot but think, therefore, that a study of the extensive work actually carried out in marl in the vicinity of Jordan Level, would have indicated the proper methods of construction to use in that material.

In regard to the expensive method of piling and cross-bracing finally adopted, the writer understands that it has been only moderately effective. Slides of the slopes still occur. As to the extent of these, it is hoped that Mr. Landreth will give an account in his final discussion.

EDWARD P. NORTH, M. Am. Soc. C. E.—Mr. Rafter's remarks are Mr. North. pertinent, but possibly he has missed, or has not emphasized sufficiently, the principal difficulty, namely, the errors made in planning the work. These errors may possibly be shown to the best advantage by Table No. 4, which gives the Engineer's estimate of quantities and prices, the contractor's bid on those quantities, and the approximate final estimate as given by the author.

It was estimated that more than 6 miles of swamp could be drained and kept free from water at a cost of \$1 500. It was this lack of appreciation of the influence of water on marl and clay that nullified the contract; for, after the first season, there was virtually no contract between the State and the contractor, but, to use the words of L. E. Cooley, M. Am. Soc. C. E., "the contractor had a license to prosecute the work at his own price and on his own specifications."

It was well known that with the first canal, built in 1816 to 1825, there was much difficulty on what became known as "the Jordan Level." It was not then as notorious as it was under the enlargement of 1836. The author has stated that three contractors abandoned the work, and that, eventually, the bulk of it was done by the State. The prism of the canal, however, was not thoroughly excavated, and when that was done there was a saving of one-third in the traction necessary to draw a boat through it.

Without an engineer's knowledge of the work to be done and an engineer's plan on which to do that work, it is impossible to cope satisfactorily with difficulties which may arise. This statement is made in emphasis of, rather than in opposition to, anything Mr. Rafter has said. The relations between the specifications and the economical and possibly the successful conduct of the work is rather interesting in view of the recommendation of the Canal Committee of the State of New York, which has recently made a report on the subject. In relation to the crying evil of unbalanced bids, and it has been a crying evil on the canal ever since 1836, the committee proposed to take action by making a schedule of prices, as the French do, in which the price of each item is fixed, and then allowing the contractor to bid either a discount or a premium on those figures. This would apply to all figures; thus, if the price of earth was 30 cents, and of rock 90 cents, a contractor might bid a discount of 1%, or a premium of 2%, and it would affect both the earth and the rock. The plan proposed would apparently eliminate all trouble caused by unbalanced bids, but it would be without influence on imperfect specifications, and the great expense incurred on Section No. 4 of the Middle Division was caused by imperfect specifications as well as lack of engineering knowledge in handling the work. The case was atrocious. The contractors bid \$3 000 to drain 6.3 miles of swamp. They were allowed to close the natural watercourses which drained into the canal and thereby turn

Mr. North. TABLE No. 4.—PRELIMINARY ESTIMATE, SUCCESSFUL BID AND APPROXI-

ENGINEER'S ESTIMATE.				
Quantities.	Units.	Items.	Prices.	Aggregate.
1	.....	Grubbing and clearing.....	\$500.00	\$500.00
1	.....	Bailing and draining.....	1 500.00	1 500.00
150 000	Cu. yds.	Dry excavation of earth.....	0.27	40 500.00
4 500	"	" " rock.....	1.00	4 500.00
500	"	Excavation of masonry.....	1.00	500.00
5 000	Sq. ft.	Rock channeling.....	0.25	1 250.00
1 000	Cu. yds.	Embankment.....	0.25	250.00
17 000	"	Lining.....	0.60	10 200.00
1 000	"	Puddling.....	0.15	150.00
500	Lin. ft.	Piles delivered.....	0.15	75.00
500	"	" driven.....	0.10	50.00
50 000	"	Piles at foot of walls delivered.....	0.10	5 000.00
45 000	"	" driven.....	0.05	2 250.00
1 000	Feet H.M.	White oak timber and plank.....	40.00	40.00
4 000	"	Pine ".....	25.00	100.00
246 000	"	Hemlock ".....	16.00	3 936.00
755 000	"	Spruce ".....	17.00	12 885.00
850	Cu. yds.	Bridge abutment culvert and receiver masonry	6.50	5 525.00
40	"	Coping on above.....	12.00	480.00
50	"	Vertical wall in Portland cement.....	5.00	250.00
1 100	"	" laid dry.....	3.00	3 300.00
16 000	"	Slope and pavement wall.....	2.25	36 000.00
2 300	"	Portland cement concrete.....	5.00	11 000.00
5	"	Asphaltic concrete.....	10.00	50.00
10	"	Loose stone filling.....	1.25	12.50
10	Sq. yds.	Portland cement pointing.....	0.30	3.00
44	Cu. yds.	Pavement wall.....	3.00	132.00
500	Lin. ft.	Cedar posts set.....	0.10	50.00
1 000	Lbs.	Wrought iron and steel.....	0.04	40.00
15 000	"	Cast-iron pipe.....	0.02	300.00
3 500	"	Spikes and nails.....	0.05	175.00
3	.....	Raising bridges.....	40.00	120.00
3	.....	Painting bridges.....	40.00	120.00
				\$141 198.50

* These piles were at various prices.

the swamp into a pond. They knew that the banks were soft and slippery, and yet they were allowed to surcharge them with the material excavated from the canal.

The bottom of the bank on the berm side averaged 40 ft. in width, and the height was about 8 ft.; on the tow-path side the dimensions were somewhat greater. As a result of establishing and maintaining a pond of water behind this bank it was impossible to excavate the material or lay slope walls.

Instead of holding the contractors to their contract they were given an easement of more than \$46 000 in the items of digging ditches, and a payment of \$2 400 for pumping.

MATE FINAL ESTIMATE ON CONTRACT NO. 4, MIDDLE DIVISION, ERIE CANAL. Mr. North.

SUCCESSFUL BID.		APPROXIMATE FINAL ESTIMATE.		
Prices.	Aggregate.	Quantities.	Prices.	Aggregate.
\$500.00	\$500.00			\$1500.00
3 000.00	3 000.00			4 825.00
0.274	41 250.00	306 164	\$0.274	84 745.10
1.00	4 500.00	25 062	1.00	25 062.00
0.70	350.00	526	0.70	368.20
0.10	500.00			
0.30	300.00	31 060	0.30	9 318.00
1.00	17 000.00	58 915	1.00	58 915.00
0.30	300.00			
0.10	50.00	440 001	*	57 400.70
0.15	75.00	392 650	0.45	58 897.50
0.09	4 500.00	84 088	0.09	7 567.92
0.09	4 050.00	44 688	0.09	4 021.92
50.00	50.00	250	50.00	12.50
30.00	120.00	19 650	30.00	589.50
16.00	3 936.00	1 055 600	16.00	16 889.60
17.00	12 835.00	220 860	17.00	3 924.62
7.00	5 950.00	705.5	7.00	4 988.50
16.00	640.00	29.4	16.00	470.40
6.00	300.00	2 859.9	6.00	17 159.40
3.50	3 850.00	295	3.50	1 032.50
2.47	39 520.00	44 800	2.47	101 656.00
5.00	11 000.00	4 200	5.00	21 000.00
15.00	75.00			
2.00	20.00	359.5	2.00	679.00
0.50	5.00	240	0.50	120.00
5.00	220.00	44	5.00	220.00
0.40	200.00	680	0.40	272.00
0.05	50.00	45 240	0.05	2 262.00
0.02	300.00	176 440	0.02	3 528.80
0.05	175.00	38 000	0.05	1 900.00
300.00	900.00	4		1 560.00
100.00	300.00	3	100.00	300.00
	\$156 821.00			\$491 076.16
		Add to this:		
		Extra work.....		33 337.17
		Force account work.....		80 982.14
		Total.....		\$605 395.47
		An increase of 286% over the price bid by the contractor.		

See Table No. 2, p. 579.

At first it may seem somewhat brutal to the contractor to say that he should have done his work at the price bid, but the case of the Chicago Main Drainage Canal might be cited, where contracts were taken with somewhat the same mental attitude as that of the contractors on Section No. 4. When the contractors said they wanted relief they were told that no relief would be granted, but that, as their sureties were abundant and satisfactory, if the work was not done by them, it would be done by the Main Drainage Commission and paid for by the sureties. After a time the contractors did the work, and not only without loss, but at a rumored profit of about 50 per cent. In relation to this work, the engineers of the Main Drainage Canal said, with

Mr. North, pride surely, and possibly with justification, that the Chicago contractors, paying \$1.50 for their poorest workmen, could have constructed the North Sea and Baltic Canal, for which the German engineers paid 75 cents for their best workmen, and have made more money thereon than the Germans.

The entire science of handling earth and rock (quicksand and hardpan being included with earth), has been advanced more materially by the attitude assumed on the Main Drainage Canal than by any other act by engineers, directors or commissioners during the preceding ten or fifteen years. The speaker thinks that if the State Engineer had said to the contractor, "You are worth more than this can possibly cost, and I will take the last cent you have and finish that work," that the work would have been done at the contract price without much loss.

The literature on quicksand is not, on the whole, voluminous, and greatly lacks defining power. Mr. Hazen's discussion probably gives the most definite information on record, and the most workable theory for quicksands which do not contain clay. But it is immediately seen that a sufficient volume and velocity of uplifting water would turn a boulder bed into a quicksand for the time. The material, however, would become firm immediately on the withdrawal of the upward current. This cannot be asserted of a true quicksand. The relations between the included water and the earth are, in some quicksands, mysterious, and while all quicksands become stable when dry, others, particularly those containing clay, will quake after they are apparently dry.

The late Charles L. McAlpine, M. Am. Soc. C. E., describes a quicksand of the last-mentioned variety very fully in a paper read before the Society in 1881.* In it he says:

"Although its name conveys the idea of a mass of sand, surcharged with water until it becomes 'quick,' or susceptible of easy movement or agitation, suggesting actual life, yet engineers know only too well that this is not the most troublesome member of the family.

"The one that causes the most trouble, and is here treated of, is an argillaceous material containing no siliceous or grit, comminutes completely, and is usually leaden in color in its natural state, and nearly white when thoroughly deprived of water.

"So free is it from sand that it can be used with good effect in polishing or cleaning silver and the softer metals.

* * * * *

"As far as possible, all traveling over the surface while being thus ditched was prevented, as it agitated the material, and caused it to retain the water more obstinately.

"After a night's quiet rest, and the great withdrawal of water through the ditches, the surface was in good condition for excavating and the material, in the words of the workmen, would then 'shovel like ashes.'

* * * * *

* Transactions, Am. Soc. C. E., Vol. x, page 275.

"Care should always be had to withdraw the men and teams at Mr. North. once from any place which indicates that it is again becoming 'quick,' from the disturbing effect of repeated traveling over its surface.

"Nothing is gained by working longer, when this important question of rest is involved.

* * * * *

"A lump of this quicksand, apparently dry, may very often be made 'quick' by a little agitation alone.

"Hard and apparently dry lumps will often become wet and pasty on their way to the dumping ground, so much so as to require additional labor to remove them from the carts."

That all of the above did not preclude, in Mr. McAlpine's mind, such quicksand as specified by Mr. Hazen, is shown by the following quotation:

"It may be assumed generally that the special mobility of such sands depends upon the presence of water filling the interstices of the mass. The mass yields to pressure in conformity to the laws of liquids or semi-fluids, varying with the degree of quickness. The degree of quickness depends upon, *first*, the gravity of the sand; *second*, upon the smoothness of the surface of the particular grains of sand; and *third*, upon the abundance of the water present with it."

Mr. McAlpine may have misnamed the material quoted, but many engineers have met with something very like it, and it is generally called quicksand.

While it cannot be doubted that quicksand may be entirely free from clay, like the samples referred to by Mr. Hazen, it seems equally certain that sand, in the usual acceptance of the term, may be wanting, or that clay which on drying becomes hard and resonant when struck can be washed from some, if not many, samples of quicksand.

JAMES OWEN, M. Am. Soc. C. E.—The speaker has held ideas on Mr. Owen. the difference between ordinary sand and quicksand, which can probably be illustrated best by a comparison between a pile of loose rock, as the ordinary sand, and a pile of cobblestones, as the quicksand. That is, quicksand is merely rounded sand, water-worn or air-worn, and, while Mr. Landreth has made a distinction by including a proportion of clay, Mr. Hazen seems to have ignored that classification.

Some years ago the speaker was asked to report on a foundation for a six-story building, of which a large proportion of the weight was to be concentrated upon one column. Sand, which was thought to be quicksand, had been encountered in the excavation, and it was a question as to whether or not it would be safe to place a large mass of concrete on it. After examining the sand the speaker reported that it was the ordinary wedge-shaped, sharp-edged sand, and that there was no fear of any flow. The building was erected, and no settlement occurred. If the speaker had found that the grains were rounded, he would not have dared to put the structure on it.

To classify quicksand in any other way than by the rounded character of its particles opens the field of speculation, and clouds some-

Mr. Owen. what the broad definition upon which engineers have depended for a number of years. For this reason the speaker believes that it would be well to determine now the difference between quicksand and ordinary sand.

The principle of the wedge-shaped sand is very forcibly illustrated by the practice of the French engineers in building one of the bridges over the Seine. The ends of the centers of the bridge were supported on large boxes of sand. The boxes had loose tops, and the longitudinal frames of the centers rested thereon. There was a faucet at the side of each box, and, when the centers were to be struck, they simply opened each faucet and the sand flowed out slowly with a certain velocity. By this means the centers were lowered very carefully and without shock to the structure.

The sand used was the ordinary cubical sand, and the vertical pressure had no effect on the flow. The sand fell on account of its own gravity alone. If the sand grains had been of rounded form, they would have flowed out with a velocity due to the pressure upon them.

Mr. Hill. GEORGE HILL, M. Am. Soc. C. E.—Some years ago, in excavating for the foundations for the *Mail and Express* Building, in New York City, the speaker encountered an extremely fine micaceous sand, designated by the contractor as quicksand. It was ascertained that the Western Union Building, adjoining, was founded on soil of the same character, and that the foundations were sustaining safely a load of about $3\frac{1}{2}$ tons per square foot. On the site of the latter building there were driven wells which had been used for water supply some years previously. After pumping for a short time the water began to appear slightly cloudy, and the building began to settle. When the pumping was stopped, the building stopped settling.

The pressure on the foundations of the *Mail and Express* Building is about $3\frac{1}{2}$ tons per square foot, and the building is standing satisfactorily. There was an initial settlement, uniform throughout the entire building, of about $\frac{1}{8}$ in., compressing the top sand, after which there was no further movement.

Within a year thereafter the speaker designed the foundation for the Pierce Building, with unit loads of 6 tons per square foot, standing on a mixed gravel and sand with rounded edges, about 18 ins. below the water-line, and with no egress for the water. That building stood satisfactorily, without any settlement.

Some years later, the Exchange Court Building on lower Broadway was erected, the excavations being carried about 5 ft. below the water-line. The character of the sand above the water-line was identical with that at the *Mail and Express* Building. As the excavation was carried below the water-line, the sand began to flow in, in spite of rather carefully driven sheet-piling for the foundation pits, the

rapidity of the flow increasing with the depth. In one of the pits, Mr. Hill, about 6 ft. square, nearly a cubic yard of sand came in during the night.

It seems to the speaker that Mr. Hazen's definition of quicksand is more nearly correct than that in common use in New York City, but errs in omitting recognition of the qualification that it is not quicksand unless there is a vent for the water. That is, a material may possess all the elements of quicksand, and yet be perfectly stable and safe to use for foundations until a vent is provided for it. If such a material is called quicksand, the owner imagines that the building must sink into it, is alarmed, and harm is done; if a proper design is adopted for the foundation the material is not, and probably never will be, quicksand. Any sand which is fine is called quicksand by contractors, and they invariably claim that it contains loam. By mixing with water, shaking up, and drawing the water off, the speaker has tried to ascertain whether or not there actually was any loam or clay in much of the material called quicksand, but, so far as he has been able to see, there is no clay, but the sand is very fine. The micaceous sand is excellent for foundation purposes, and, although slightly compressible, is absolutely safe if there is no vent for it. If water is present and there is an opportunity for it to flow off, even though there may not be an excess of moisture, the material will flow.

J. G. TAIT, Assoc. M. Am. Soc. C. E.—The speaker is pleased that Mr. Tait, the discussion has avoided the canal portion of Mr. Landreth's paper, and has brought out the interesting discussion on quicksand. The speaker wishes to correct any false impression which Mr. North's remarks might convey to any member not familiar with the contracts and specifications of the \$9 000 000 canal improvement. Mr. North states that the contractor got \$46 000 extra for bailing and draining, which he should have been made to do for the original bid of \$3 000. The \$46 000 was paid to the contractor at the very low excavation price of 27½ cents per cubic yard for material removed in a swamp when constructing side ditches at a loss, and these should have been estimated originally by the engineer, therefore this sum was not a present.

There was a great deal of extra work on this contract, which should, and usually does, represent some profit, but the sub-contractors, who got these supposed benefits, are bankrupt to-day. The unusually good quality of the work done, the favors demanded of the contractor, and the final non-payment for work done, through selfish, incompetent State officials, made the Erie Canal experience very costly for the majority of the contractors.

The competition in contracting to-day causes very low prices, and in a lengthy or obtuse specification, a contractor, to get the work, has to take the cheapest interpretation of what he is to be required to

Mr. Talt. do, and bid accordingly. Nearly all the contractors with whom the speaker is acquainted are men who will accept the loss due to a misinterpretation, and who will do the work required by the specifications and contract, but when, in a contract calling for thirty-nine items, one alone of which, in a total of \$154 000, increases from \$3 000 to \$49 000, and is decidedly the fault of the contract and plans, the speaker cannot understand how an honest or fair-minded man, particularly one familiar with all the conditions, can state that the contractor should have been made to do this enormous necessary amount of extra work for nothing.

Instead of taking from or injuring a contractor who has so much with which to contend, the engineer and contractor should both work together for the good of the work, the engineer seeing that he gets his money's worth, but at the same time not using his power to get something for nothing, an old-time policy not followed by all engineers.

Quicksand, with which the speaker has had considerable experience during the past twelve years, is such a bugbear that when contractors encounter any kind of moist sand it is quite natural for them to call it quicksand, as Mr. Hill remarks.

Any sand, even the sharp angular kind, will run, even if it is under a head of only one foot, but if it contains no clay, or if the grains are not rounded, it can be controlled readily by sheeting and pumping. On the other hand, if the sand is fine and rounded and contains clay, great trouble is experienced. Even in cases where the sheeting is driven far below the bottom of the excavation, this material may rise in the center and cause the sides of the excavation to cave in, thus producing excessive or unbalanced pressures on the sheeting.

Mr. Whinery. SAMUEL WHINERY, M. Am. Soc. C. E.—It would be very desirable, if it were possible, to have a correct and comprehensive definition of quicksand, but the speaker's experience has been (and he thinks it is the experience of many others), that, after settling upon what seemed at the time to be the proper definition, the very next case is likely to contradict it entirely.

During the construction of a railroad in Western Indiana, some 30 years ago, in making a cut not far from a stream, but well above its water level, quicksand was encountered by the plows and scrapers and stopped the work at that point. In investigating in a rude way it was found that 10-ft. fence rails could be pushed down for their full length quite readily without reaching the bottom of the quicksand.

The sand was very fine, and was almost free from any admixture of clay or other foreign matter. Apparently, there was no possibility of the existence of the conditions to which Mr. Hazen refers, that is, of its being buoyed up by a rising current of water. It is true, the

sand was filled with water, but this water was, apparently, in a Mr. Whinery. quiescent state. There were no springs known to exist in the vicinity. The depth of the deposit was not ascertained, but it seemed to be contained in a pocket surrounded by impervious clay. The case was dealt with by beginning the excavation at the lower end of the cut, where the grade was lower, and working up the grade with deep side ditches until the deposit was reached. The water in the sand then drained out, the material became quite hard, and was then excavated with plows and scrapers. The sides of the cut were dressed to the usual slope, and they have stood quite satisfactorily ever since.

L. J. LE CONTE, M. Am. Soc. C. E. (by letter).—This paper is full Mr. Le Conte. of information not often found in print. Engineers are generally chary about publishing accounts of their troubles in practice, and rightly so, because the irresponsible critic is the most active of all.

When working in treacherous ground, such as described in the paper, the engineer is often at his wits' end to know the best way to meet existing conditions. In many instances it seems as if Nature took a malicious delight in defying all the requirements of the best laid plans and specifications, based on the most trustworthy information.

The troubles depicted so graphically by the author excite the interest and sympathy of any engineer who has had the misfortune to be caught in such a trying position. The simple and effective methods adopted to overcome local obstacles are certainly highly commendable.

The laws of hydraulics and hydrostatics have been well developed by experimental investigators, but the laws governing the dynamics and statics of mud have yet to be formulated in practical shape. In June, 1826, at "Chat-Moss" on the Liverpool and Manchester Railroad, 4 miles of embankment cost nearly \$150 000, and took 7 months to complete. The indomitable pluck and tireless energy of the engineer, George Stevenson, prevailed finally and left a monument to his name.

The writer was interested in a case which was particularly trying, and, at first sight, seemed to be impossible of solution.

A proprietor desired to improve a tract of marginal marshland by raising it well above the effects of tide water in a lake. The marshland was underlaid by plastic blue mud which rested upon a solid bed of yellow clay hardpan, the latter having a natural slope of about 13% toward the lake. The mud, at high-water line, was about 40 ft. deep, making the outlook rather unfavorable. The case was complicated still further by the proximity of a deep-water channel and a system of tidal sluice gates in front of, and parallel to, the shore line. This channel could not be encroached upon by pushing out the marsh mud under the pressure of the proposed new filling. The problem was, nevertheless, solved successfully as follows:

Mr. Le Conte. *First*.—A trench 4 ft. x 12 ft. wide was excavated along the irregular line of high water or outer edge of the marshland. The material taken out was deposited on the edge of the trench next to the high land, the top width of the bank being sufficient for two runways for wheelbarrows.

Second.—The work of filling in with heavy sandy material was then begun, at and along the segregation line, advancing gradually toward the lake. As the filling progressed, of course, settlement commenced, and the material in the bottom of the trench began to rise up. A force of 100 laborers and excavators had all they could do to excavate and remove the material from the rising bottom as fast as it came up. This process was continued until the entire marshland was filled in solid down to hardpan, and all settlement had stopped. It is a notable fact that the total yardage thus taken out from the bottom of the trench was approximately the same as the total yardage of heavy material in the filling below the level of the marshland, namely, some 140 000 cu. yds., and yet, after the completion of operations, the dimensions of the trench were the same as in the beginning.

It would appear, therefore, that the trench simply afforded a natural vent for the escape of imprisoned mud compressed by the weight of the advancing filling deposited on the marshland. By this means these lands were filled in successfully without crowding the mud into the channel-way in front of the property to any appreciable extent.

Mr.
Richardson.

CLIFFORD RICHARDSON, Assoc. Am. Soc. C. E. (by letter).—It may be of interest, in connection with the discussion of the subject of quicksands, to present some data in regard to the actual size of the particles in several such sands which have recently been examined in the New York Testing Laboratory by the writer.

These sands were from the following sources:

No.	SOURCE.
	NATIONAL CONTRACTING CO., BOSTON, MASS.
11 541	Neponset Valley Sewer, Section 26, Station 3 + 50. " When wet, extremely difficult to handle."
11 542	Neponset Valley Sewer, Section 26, Station 2 + 80. " Found under peat. Very troublesome to excavate, and difficult to hold trench in line and grade."
11 544	Neponset Valley Sewer, Section 26, Station 1 + 37. " Very difficult to handle. Squeezes trench badly."
	H. P. EDDY, SUPERINTENDENT OF SEWERS, WORCESTER, MASS.
30 723	Greene Street Sewer
30 724	" "
30 725	" "
	} see <i>The Engineering Record</i> , March 24th, 1900.

For comparison with these sands, the finest ground limestone produced in a Danish tube mill, all of which passed a 200-mesh sieve, was examined.

The sands, Nos. 11 541, 11 542 and 30 725, under the microscope, were seen to be very clean, and to be made up of extremely sharp grains with no clay. Sands Nos. 11 544, 30 723 and 30 724 were equally sharp, but carried a small amount of clay, amounting to less than 1%, and not subsiding from water in a week.

The voids in the hot sand, compacted thoroughly in a 100-c. c. cylinder by shaking and tamping, were determined, where sufficient material was available, and from them the volume-weight per cubic foot. These sands were finally sifted on sieves, and elutriated by the beaker method. In this way they were divided into grades of particles of different sizes. The results are shown in Table No. 5.

Sand No. 11 541 has a wide variation in the size of its particles; consequently, it has low voids and high volume-weight. Sand No. 11 542 would probably show like characteristics, but, with a somewhat wider grading, somewhat lower voids. Each of these sands contains a very considerable amount of grains of high hydraulic value, as do the Worcester sands, Nos. 30 723 and 30 724, with voids much like those of sands used in ordinary mortar—36.7 and 34.7 per cent.

The most interesting sands are the two extremely fine ones, Nos. 11 544 and 30 725. They are of very uniform grading, the majority of the particles being of sizes within very narrow limits. The resulting voids are, in consequence, what are usually found under such circumstances, about 40 per cent.

TABLE No. 5.

Nos.		11 541	11 542	11 544	30 723	30 724	30 725	Finest ground limestone.
Voids in hot compacted sand		29.3%	.....	40.2%	36.7%	34.7%	.....	39.3%
Weight per cubic foot, in pounds.....		117.2	.....	99.1	103.8	106.1	.....	100.4
Sieve.	Diameter, in millimeters.							
.....	0.035	19.2%	11.2%	65.5%	47.2%	11.6%	79.7%	63.5%
.....	0.065	7.9%	14.2%	13.7%	19.6%	11.4%	9.5%	17.7%
200	0.09	18.3%	19.6%	16.8%	11.2%	9.0%	9.8%	18.8%
100	0.17	34.0%	22.0%	3.0%	13.0%	39.0%	1.0%	.....
80	0.23	11.0%	8.0%	1.0%	4.0%	12.0%	.....	.....
50	0.31	7.0%	16.0%	.....	3.0%	10.0%	.....	.....
40	0.50	1.0%	4.0%	.....	1.0%	3.0%	.....	.....
30	0.67	1.0%	2.0%	.....	1.0%	3.0%	.....	.....
20	1.00	.....	2.0%	.....	.....	1.0%	.....	.....
10	2.00	.....	1.0%	.....	.....	.....	.....	.....
Greater than	2.00	.....	2.0%	.....	.....	.....	.....	.....

The sizes of the grains of these sands are smaller than those in the ground limestone dust, that is to say, than the finest Portland cement.

Mr. Hazen's claim that quicksand depends more for its peculiarities upon the size of the particles and upon their small hydraulic value

Mr. Richardson. than upon any other characteristics, round shape of grain, presence of clay, etc., seems to be confirmed.

It would be of interest to examine the quicksands encountered in the Erie Canal in the same way, and the writer would be glad to do so if samples from that locality, and from any others where such sands are met, can be furnished.

Mr. Cooley. L. E. COOLEY, M. Am. Soc. C. E. (by letter).—Mr. North has referred to the work on the Chicago Main Channel. The treacherous ground on this work extended over 6 to 8 miles, and included a wide variation in the material, of which the amount was several million yards. The history of this work has shown that by hydraulic dredging, or by drainage, large channels can be cut through such material as cheaply as through stable ground. To present the subject, however, opened so wide a field and involved so much labor, that the writer has been disposed to defer any remarks until some more zealous member had presented the Chicago experience.

Quicksand has come to be a broad generic term referring to any material containing usually a large proportion of silicious grains, as distinguished from mud, or other material with a large proportion of clay which shrinks and cracks on exposure. All these materials are stable when the excess of water is removed. Some of them are so finely divided or contain so much clay that they drain or leach out very slowly. Others are so coarse or drain so freely that they can hardly be called "quick," but have been called "alive" under conditions, usually temporary or special. Again, some materials, when once handled, are comparatively stable under new conditions of saturation. That material should be "quick," is due to a condition with respect to water, rather than any quality inherent in the material itself. A monograph is required to discuss fully the subject—"quicksand."

A large range of sands is mobile under the conditions cited by Mr. Hazen; in fact, very coarse material would be unstable under upward flow. The writer has sunk hundreds of piles "butt down" by means of a water jet and without guides or hammer. The material around the pile was kept "alive" by "weaving" or partial rotation. Fishermen about the lakes set poles in 20 ft. of water, or deeper, by "weaving." The material is not necessarily "quick."

Running sands are largely due to the escape of contained waters; to crevasse action rather than any flow *en masse*. Some initial restraint will often prevent this until partial drainage has insured against displacement. The marginal deposits of the Missouri, below mid-stage, are usually quite fine, and become "alive" under the driving of a survey stake, or very active tramping, and the writer has seen the same on the beach of Lake Michigan. Such sands will drain very quickly, almost instantly, and have then no suggestion of instability.

Passing back from the immediate shore of the Missouri to places

sheltered from the high-water current there will be found deposits of Mr. Cooley. finer sand mixed with "gumboe," and these remain "quick" for weeks or months, according to the proportion of clayey material; and finally, this may be so much in excess as to make virtually a mud deposit which cracks on drying. Most of these deposits do not become unstable under subsequent high-waters. Even the yellow bluff deposits, which are very porous (roots penetrating deeply), and which remain perfectly firm under ordinary rain, will become saturated and temporarily "quick" under heavy downpours. This material contains enough clay to puddle, and can be burned into brick.

The study of the deposits of a stream like the Missouri and the source thereof in its water-shed, from the mobile, alkaline clays of the "bad lands" to the coarse granitic sands and the lavas, gives a glimpse into the genesis of the whole tribe of quicksands.

The sortings of the waters in the working over of glacial grindings differ only in age and source of material. Localities may add the results of animal and vegetable life in the marls and mucks. That these deposits should be, or should continue to be, unstable, is largely due to lack of drainage.

On the Chicago Canal were some $2\frac{1}{2}$ miles of muck and mud deposits from 10 to 30 ft. deep, which were removed by hydraulic dredging to a width considerably greater than the channel. The underlying material was dredged and placed on the berm to form the proper banks. The prism was then pumped out and completed "in the dry" in perfect security. In carrying a levee line through this material it heaved in places for 100 yds. distant. Very little seepage occurred, though the Desplaines River was scarcely 100 yds. away, with nearly 40 ft. of head over grade at high water.

For about $1\frac{1}{2}$ miles there were also deposits of muck, marl and mud, in which an iron rod could be shoved down. In the original construction of the Illinois and Michigan Canal, the towpath had been carried on a trestle, and in the deepening of the same the area was a quaking bog, and the prism of the canal called for much redredging in its formation. Various expedients were resorted to at the outset. A part was handled by hydraulic dredging. Eventually, it was discovered that the material could be slowly relieved of its excess of water by continued pumping, and that it could then be handled with the greatest facility by ordinary methods.

Another $1\frac{1}{2}$ miles contained beds of indurated material and heavy beds of quicksand. The most vexatious of this acquired the local name of "bull-liver." No treatment could be decided upon. Meantime, continued pumping had so relieved the situation that, as the work progressed, the "quicksand" came to be the only easy part of the excavation. The writer is of the opinion that there were a couple of miles more of "quicksand" that never showed itself to the con-

Mr. Cooley. tractor. The writer has waded through the gray, fine and dry dust well down in the channel on a hot day, when it seemed to be a section of the arid regions. Systematic drainage had changed its character before it was reached.

Water was the great bugbear of the Chicago Main Channel, and the writer was substantially alone in advocating its construction "in the dry." Although great difficulty was anticipated from this source, and elaborate consideration given to the handling of water, it proved to be entirely overestimated. This great canal, cutting all the strata for 28 miles to a depth of 35 to 40 ft., hardly produced enough water to supply a city of 100 000 inhabitants, after the ground-water reservoir had once been drained; and all the run-off from 700 miles was carried within less than $\frac{1}{4}$ mile for 20 miles on one side and the Illinois and Michigan Canal within a like distance on the other for the entire length. There were 9 miles of rock, carrying some water, at localities, and 7 miles of clay; but there were 12 miles with all the variety of formation that can be imagined in an ancient stream bed of the glaciated regions.

The use of gravel, hay, sods, brush and similar material in minor excavations to check running sands until they can drain, is well understood.

Wells may be very effective in draining out ground-water, and it is surprising how little additional water may be developed by an extensive cutting over that encountered in an individual well. Wells are sunk in treacherous ground on a curb, and the sinking of brick wells in India is a very ancient practice. The semi-nomads of the arid regions of Nubia have, from time immemorial, sunk wells for their stock, in depressions and draws, through wind-blown material and fine wash. A hole is scooped out and lined with a thick rope of twisted twigs and brushwood which is added in a continuous coil at the bottom as the excavation descends. Such wells reach depths of 25 to 30 ft. and more. Another device of the Nubians is a flexible or woven bucket which can be carried on the pommel of a saddle; and cooking is even done in baskets by means of heated stones.

There appears to be no reason why it should not be feasible to remove ground-water from extensive areas by systematic pumping from a series of driven wells. After the reservoir is once emptied, it will usually be found that the constant flow is limited and much less than ordinarily supposed.

Seepage from adjacent ditches and streams, even when new strata are cut, is usually much less than supposed. With roily water, stream beds choke or puddle quickly, and percolation becomes very slow or ceases entirely. Unless strata are very coarse and open, the rapidity of flow and the amount are generally overestimated if the distance be considerable, and the pumping item in extensive cuttings need not usually be a large element of cost.

A word as to specifications and unbalanced bids to which Mr. North Mr. Cooley has alluded.

The writer's views are on record in regard to the character of the Erie Canal specifications in the report of Governor Black's Committee of Investigation of expenditures under the "Nine Million Act." There is nothing in these specifications to be commended, and the French device to prevent unbalanced bids is an attempt to mitigate the evils of a system which in itself is fundamentally wrong.

The Engineering Committee of the Sanitary District of Chicago, of which the writer was Chairman, spent weeks with the aid of its Engineering Staff and its Law Department, in the consideration of specifications and contracts. The endeavor was to so frame these instruments as to conform to equity decisions by the Courts; to make the duties of the engineer purely ministerial; to reduce the bid items to the lowest number practicable and generally to leave as little as possible to future interpretation. The idea was to frame a contract for specific performance rather than a franchise for doing some unknown thing on a "piece-work and material" schedule of prices, in which the size of the pieces and the amount of material were to be determined later by discovery and by the varying idiosyncrasies of officials and the astuteness of contractors. The essence of such a contract is a knowledge of the conditions, as it is, indeed, of all contracts in the last resort of equity. The obtaining of this knowledge is a presumption of official responsibility, a requirement for public protection; and a neglect of such duty cannot be construed to work a hardship to the contractor.

This does not mean that the contractor is to base his bid on the official data in regard to quality of material, but it does mean that the work is to be so far exhibited that the contractor can form for himself a proper judgment of cost within the limits of a reasonable risk. Pumping, bailing, draining, clearing, grubbing, mucking, plant, material, supplies and a thousand things are all incident to a main purpose which can be sufficiently exhibited in a very few items, capable of reasonably close measurement for purposes of current compensation and final estimate. The specification should be full, and there may be qualifying clauses against abuse in current estimates, but which do not affect the final.

With few items, and these reasonably well ascertained, a little intelligence will prevent unbalanced bids and administer contracts to a successful conclusion, provided they are actual contracts and not permits on a "piece-work and bill of material" basis.

WILLIAM B. LANDRETH, M. Am. Soc. C. E. (by letter).—The problem presented in the improvement of the canal through the marl beds was that of deepening an existing channel and not of building a new one. Owing to the high and wide spoil banks formed by the material

Mr. Landreth.

Mr. Landreth. excavated in the first construction of the canal, the general plan proposed by Mr. Rafter, a wide channel with flat slopes, if adopted in the 1896 improvement, would have proven more expensive than the timber and pile construction.

No slides have occurred in any portion of the work described, where struts were placed across the prism. Several careful examinations of the timber construction, made by the writer during the past winter and spring, show that no movement of the struts or slope wall has taken place.

When the water was let into the canal in May, 1898, a portion of the tow-path bank, where only short piles had been used under the slope wall, slid into the prism. This slide occurred in front of the Empire Portland Cement Works, and was probably caused by the vibration of heavy engines and grinding mills in the works adjacent to the tow path. Bids were asked for in November, 1899, for the repairing of this slide, upon plans identical with the pile and timber construction used in 1897-1898, but on more stringent specifications regarding the re-excavation of material.

After several competent contracting firms had examined the locality, plans and specifications, only one contractor submitted a bid. The contract was awarded to him, and the work has been completed in a satisfactory manner for 12% less than the engineer's preliminary estimate.

The price bid for bailing and draining on the last contract amounted to \$12.50 per lineal foot of prism, and, taking the length of prism in the marl beds on the former contract as 2 000 ft., the bailing and draining on that contract would have cost \$250 000, at the same rate per foot.

The 1899 work, done by contract, on the same plan as the 1897 work and under the direction of the same engineer, cost about 20% more per lineal foot than the 1897 work done under "force account."

The case of the Canandaigua Outlet, cited by Mr. Rafter, is not a parallel case with the marl bed work on the Jordan Level; the former being a dredged channel from which the water is never removed.

The drainage ditches, noted in Mr. North's discussion are of permanent value to the State by lessening the saturation of the canal banks and preventing the surface water from entering the prism.

A calculation of the quantities on Contract No. 4, based on the system of unit prices mentioned by Mr. North, shows that there would have been a difference of about 1% in favor of the contractor, provided the prices estimated and bid had been the same as by the old method.

The discussions on quicksand treat the subject from scientific and practical points and have added materially to the literature thereon, thus attaining one of the objects in view in the preparation of the paper.